Smart Materials &
Biomedical Applications
Research and Education Center

IKBFU
IMMANUEL KANT
BALTIC FEDERAL
UNIVERSITY

Kaliningrad, Russia, 2022

Who we are

Smart Materials & Biomedical Applications
Research and Education Center

IKBFU
IMMANUEL KANT BALTIC FEDERAL UNIVERSITY

- ✓ 16 hardworking PostDocs
- ✓ 7 bright PhD students
- ✓ 9 curious students
- ✓ 9 wise adjunct members
- \+ 10-20 internships per year

More details here

Head of the REC SMBA
Assoc. Prof., Dr. Valeria Rodionova

& 19 wonderful former members forming wide collaboration network

average age of the member	29
Q1-level publications	300+
number of publications	400+
articles published in international collaboration	65%
research grants	48
IF of the journal with the highest scored publications	9.2

internships

REC SM&BA was created in 2020 and grew out of The Laboratory of Novel Magnetic Materials established in 2013.

Laboratories:

- Nano- and Micromagnetism
- Composite Materials
- Biomedical Applications
- Magnetooptical Studies
- "Digital Twins"

Address: Gaidara str. 6 Kaliningrad, Russia
Email: rodionova@lnmm.ru

Industry-Oriented Projects:

❖ **Magnetic micromanipulator**
Living cell manipulation using stray fields of magnetic microwires

❖ **Magnetooptical magnetic field sensor**
Magnetoplasmonic crystal-based sensing element with an optical detection scheme

❖ **MXene-based carbon dioxide sensor & water purification system**
Measuring CO_2 emission by detecting changes of resistivity in the MXene film & using MXenes as adsorptive agents for removal of heavy metal ions from water

❖ **Bioactive scaffolds for bone tissue repair**
Using polymer-based composites for the controlled stem cells proliferation

❖ **Magnetoelectric nanogenerators**
Transforming energy in the microwire-fiber-based composite devices

❖ **Composite materials' "digital twins"**
Developing software to create models that fully simulate composite materials

Industry-oriented studies are carried out with the wide list of collaborating groups both from Russia and abroad

Our educational program

Immanuel Kant Baltic Federal University (Kaliningrad, Russia) in cooperation with Gdansk University of Technology invites students from all over the world to enroll in the double degree Master Programme –

FUNCTIONAL NANOMATERIALS AND ADVANCED TECHNOLOGIES

The curriculum of FunNAT is designed to expand students' in-depth knowledge in Physics and Material Sciences.
Three available majors are:

- **Biomedical Applications**
- **Optics and Photonics**
- **Industrial applications**

Modern industrial and scientific technologies, applications of smart materials and nanotechnology

More details here

FunNAT education is divided into two stages:
1) classroom training and 2) experimental and theoretical research for master thesis or working on Startup projects

Choose: What to learn, Where to learn, How to learn and Who to learn from!

FunNAT features:

- **120 ECTS credits in the two-year programme;**
- **interdisciplinary courses to learn about relevant scientific topics in other areas;**
- **learning soft skills;**
- **M.Sc. in Physics degree of the Immanuel Kant Baltic Federal University.**

Nano- and Micromagnetism Lab

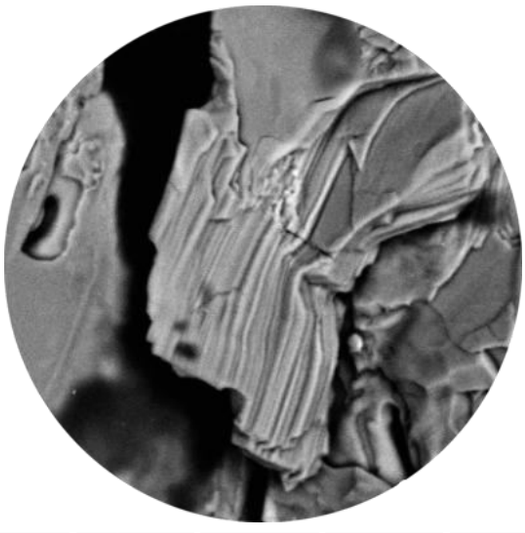
Head: Dr. Alexander Omelyanchik

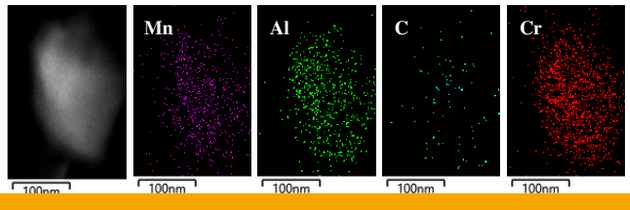
Nanoparticles, Microwires, Thin Films, MAX-phases, MXenes

Magnetic MAX-phases and novel MXenes

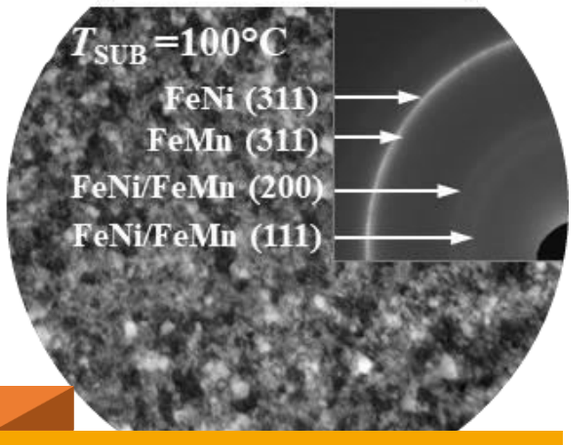
Complex optimization of the existing synthesis approaches to synthesize phase-pure and highly doped quaternary MAX-phases. Expanding the class of MAX-phases towards 3d-metal containing compounds and studying their magnetic properties.

Synthesis of novel two dimensional materials – MXenes – with variable surface functionalization and investigating them as novel adsorptive agents for the selective removal of pollutants from water and air. Using MXenes in biosensorics and biomedicine. Embedding magnetism to the class of MXenes by the controllable growth of ferromagnetic nanoparticles on top of the 2D flakes.





K. Sobolev, et al.,
J. of Mat. Chem. C, 9(46), 16516-16522, 2021
doi: 10.1039/DITC03092B



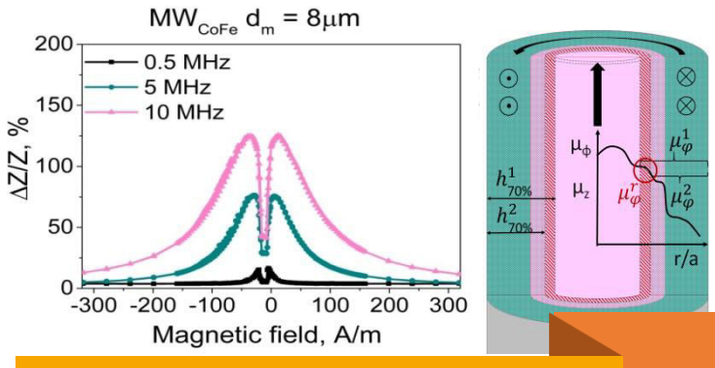
Ch. Gritsenko, et al.,
Nanomaterials, 12(7), 1178, 2022
doi: 10.3390/nano12071178

Ferromagnetic glass-coated microwires for sensors

Our goal is to precisely control micromagnetic structure of microwires is the basis for the improvement of sensor technologies. We have found a novel way to estimate the micromagnetic structure and to determine the permeability distribution in the cross-section of the wire.

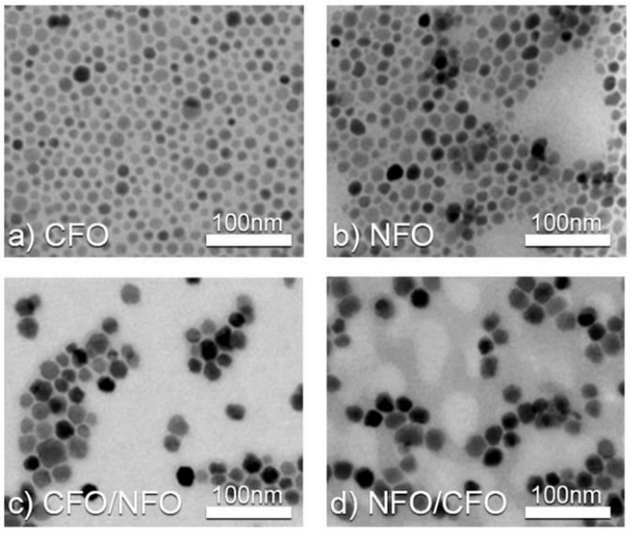
Magnetic multilayer thin films for spin valves and magnetic sensors

Development of permalloy-based thin films with mixed in-plane and perpendicular magnetic anisotropy. Tailoring magnetization reversal in exchange biased permalloy-based thin film materials.



Iu. Alekhina, et al.,
Nanomaterials, 11.2, 274, 2021
doi: 10.3390/nano11020274

Obtained results are of the high importance for embedded stress-sensor applications.



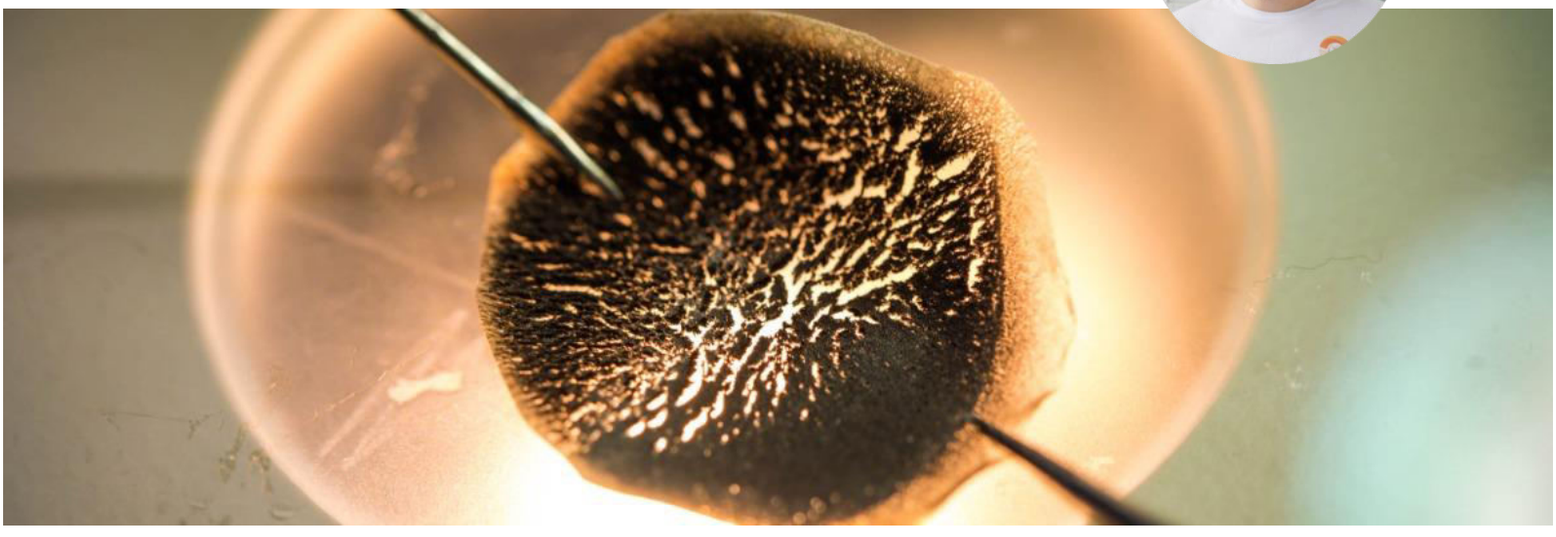
A. Omelyanchik, et al.,
Nanoscale Adv., 3(24), 6912-6924, 2021
doi: 10.1039/D1NA00312G

Multifunctional nanoparticles for biomedical and environmental applications

We apply wet chemical methods to produce iron oxide-based magnetic nanoparticles and nanohybrids of different sizes, shapes and compositions. Specifics of our research is understanding the influence of synthesis method and nanoparticle structure on the magnetic structure and magnetic behavior of nanoparticle assembly. Prepared nanoparticles can be used for biomedical applications and environmental remediation technologies.

Composite Materials Lab

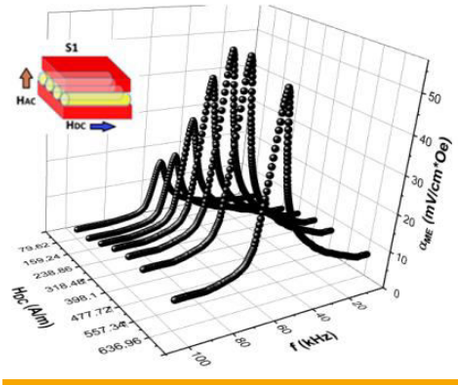
Head: Dr. Abdulkarim Amirov



Multiferroics, Polymers, Piezoelectrics, Smart Composites

Magnetic composites for sensorics

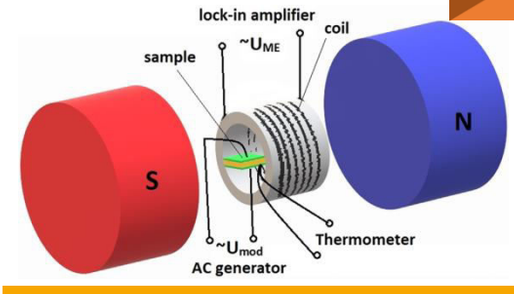
We designed and investigated magnetoelectric composites based on the soft glass-coated magnetic microwires sensitive to low (< 10 Oe) magnetic fields. Advantages of the designed composites are their multi sensitivity to various external stimuli - mechanical stress, magnetic and electric fields.



A. Amirov, et al.,
Materials, 13(4), 916, 2020
doi: 10.3390/ma13040916

Electric field control of magnetism

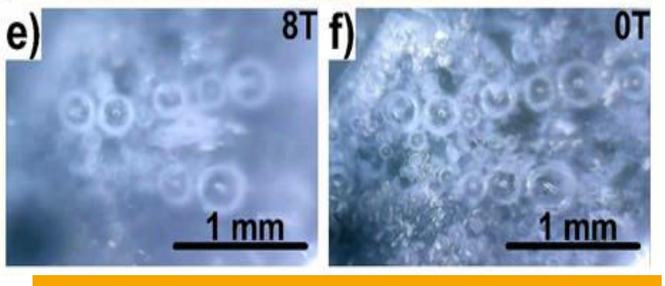
We investigated electric field controlled magnetization in bi- and tri- layer ME composites consisted of FeRh and PZT. The influence of voltage-induced mechanical stresses on magnetization was considered in both ME composites. It was shown that three-layered PZT/FeRh/PZT composite is more effective for controlling the magnetization in FeRh.



A. Amirov, et al.,
JMMM, 479, 287–290, 2019
doi: 10.1016/j.jmmm.2019.01.079

Thermoresponsive polymer composites

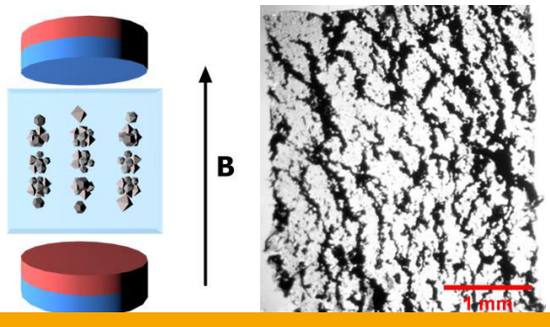
We developed new methods and technological approaches for the manufacturing of thermoresponsive smart composites, tuned by magnetic field. PNIPAM polymer was used as a temperature responsive component. It can be used in the design of smart implants with drug release functions. Physical properties (volume, hydrophobicity- hydrophilicity) of thermoresponsive polymer are controlled by the magnetocaloric effect produced by magnetic component of the composite.



A. Amirov, et al.,
Mat. Let., 304, 130626, 2021
doi: 10.1016/j.matlet.2021.130626

Magnetoelectric composites for biomedical applications

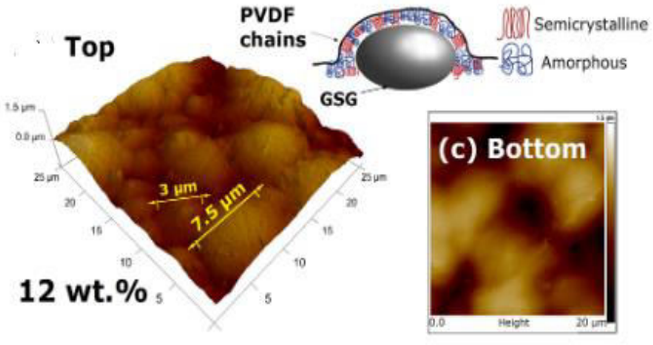
We study multiferroic composites, based on PVDF piezoelectric polymers and cobalt ferrites with controlled magnetic, electrical, mechanical and magnetoelectric properties. These composites can be used for stimulating stem cell growth under the influence of electric and magnetic fields which makes them a promising alternative to existing scaffolds.



A. Omelyanchik, et al.,
Nanomaterials, 11(5), 1154, 2021
doi: 10.3390/nano11051154

Multicaloric composites

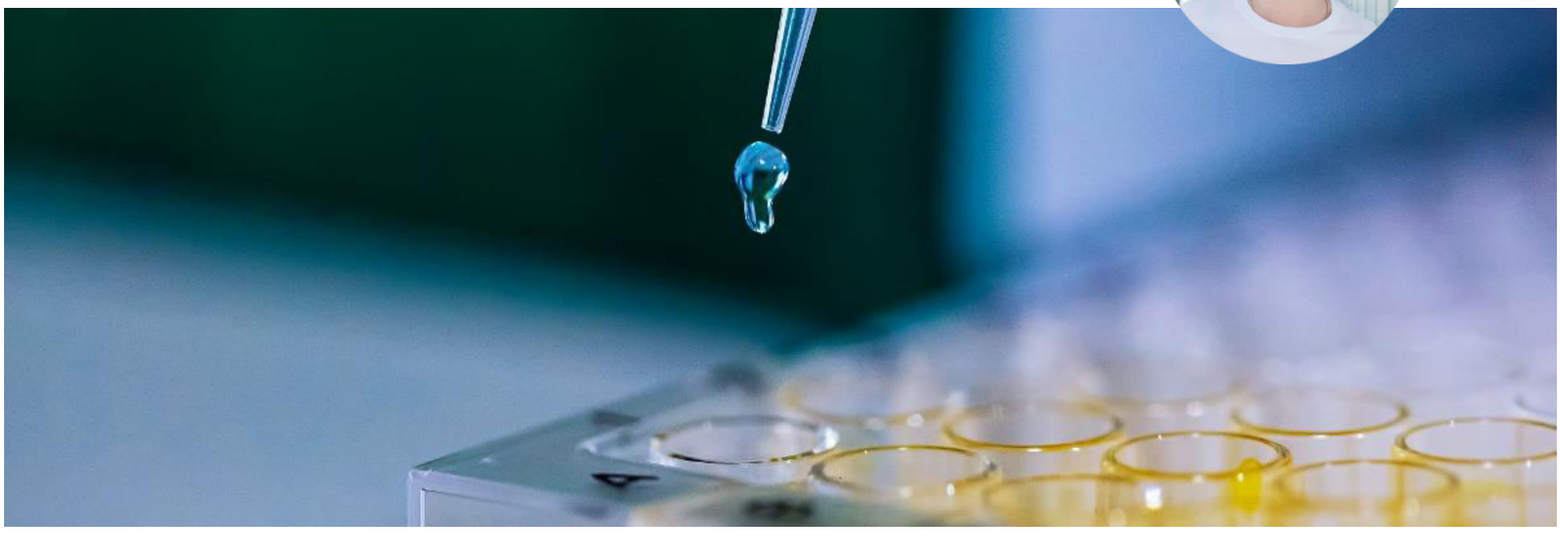
Multiferroic composites consisted of $Gd_5Si_{2.4}Ge_{1.6}$ magnetocaloric microparticles, embedded in a polymer piezoelectric PVDF matrix were fabricated. The combined magnetocaloric and magnetoelectric effect was observed at the magnetic phase transition temperature. Results reveal the potential of $Gd_5(Si,Ge)_4$ family for applications such as sensors and energy harvesting.



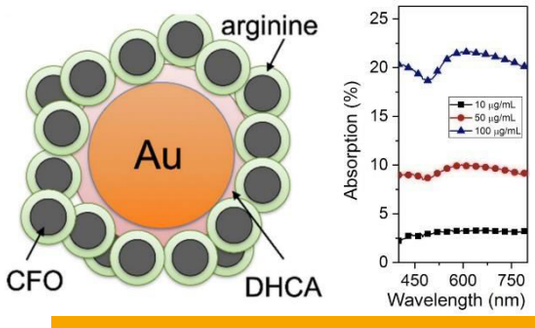
V. Andrade, et al.,
Scientific Reports, 9(1),18308,2019
doi: 10.1038/s41598-019-54635-8

Biomedical Applications Lab

Head: Dr. Kateryna Levada



Green Synthesis, Cell Signaling Pathway, Stem Cells Differentiation

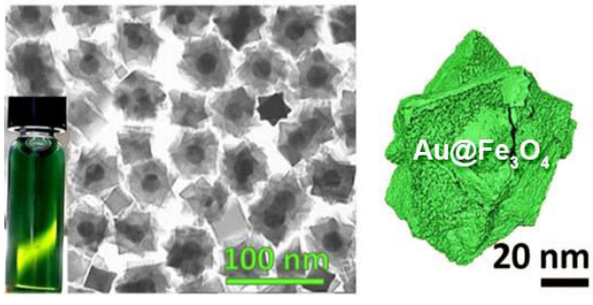


A. Motorzhina, et al.,
Processes, 9(12), 2264, 2021
doi: 10.3390/pr9122264

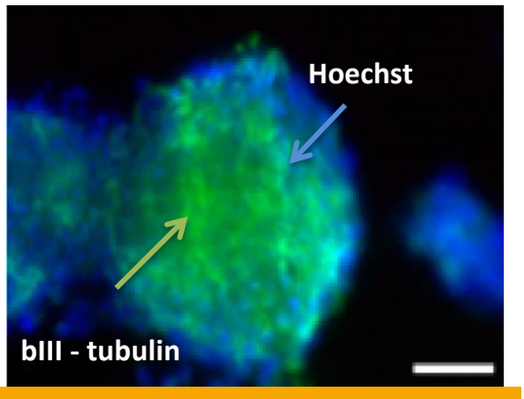
Nanocomposites for photothermal therapy

We studied nanocomposites based on gold and magnetic nanoparticles with different surface functionalization. Nanocomposites possessed localized cytotoxic effect on different cancer cell lines and can be used as multifunctional agents in photothermal theranostic techniques.

The effect depends on the optical and magnetic properties of particles and is achieved by the excitation of localized plasmon resonance in gold particles and the superparamagnetic state of ferrite particles.



B. Muzzi, et al.,
ACS AMI, 14(25), 29087-29098, 2022
doi: 10.1021/acsami.2c04865



A. Omelyanchik, et al.,
Nanomaterials, 11(5), 1154, 2021
doi: 10.3390/nano11051154

Stem cells differentiation by using smart materials

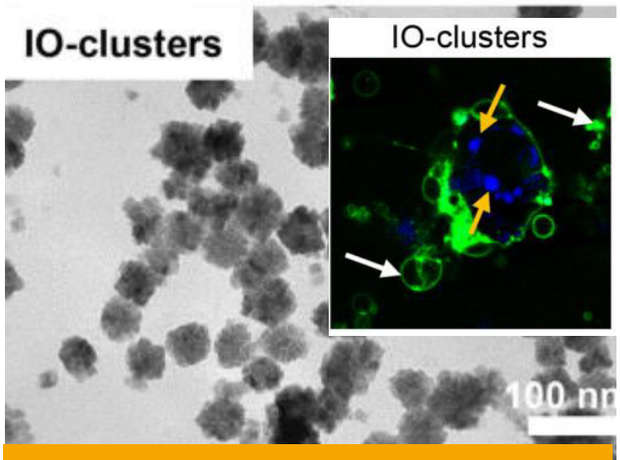
Unique properties of the smart materials give the possibility to guide the differentiation of stem cells. We demonstrated proliferation, migration and differentiation of neuronal stem cells at the early embryonic stage.

Antimicrobial activity of magnetic nanoparticles

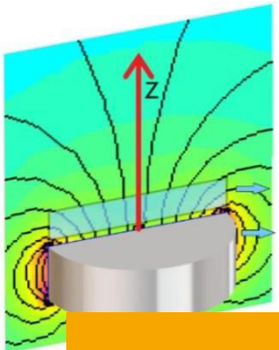
Nowadays importance to provide green synthesis and ecofriendly nano-materials has a high priority. Moreover, antimicrobial effect of ferrite-based nanoparticles can be used for the potential application in water remediation. Nanoparticles induce the lag in *E. coli* growth that correlated with the magnetic and structural properties of a spinel ferrite structure.

Application of magnetic nanoparticles in cancer theranostic

We clarified the mechanism by which cubic nanoparticles induce autophagic flux and the mechanism of subsequent toxicity, and demonstrated that different expression levels of Bcl-2 predispose cell death signaling, mediated by nanoparticles.



K Levada, et.al.,
Nano Convergence, 7, 17, 2020,
doi: 10.1186/s40580-020-00228-5



S. Pshenichnikov, et al.,
JMMM, 523, 1, 2021
doi: 10.1016/j.jmmm.2020.167623

We found an enhanced cytotoxic effect of magnetic nanoparticles on cancerous Jurkat cell line due to the induced oxidative stress after cultivation in magnetic fields. At the same conditions the viability of human peripheral blood mononuclear cells was not inhibited.

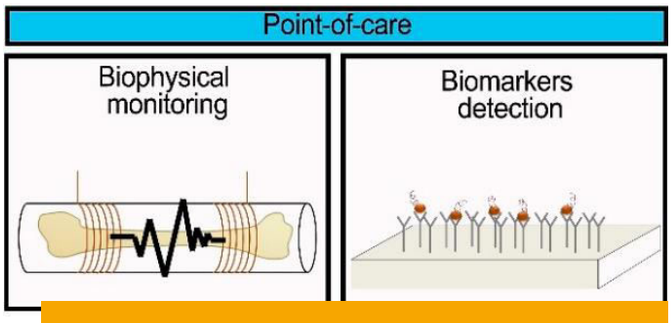
Magneto-optical Studies Lab

Head: Dr. Victor Belyaev

Spectroscopy, Magneto-optical Effects, Surface Plasmons

Ultrasensitive magnetic field sensors

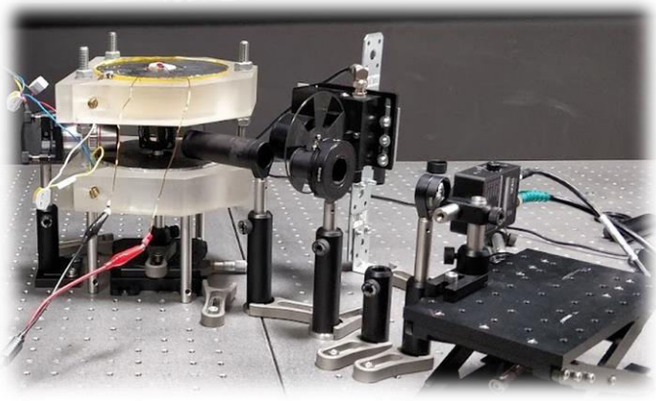
This introductory review focuses on modern magnetic field sensors, suitable for biomedical applications from a physical point of view and provides an overview of the recent studies in this field.

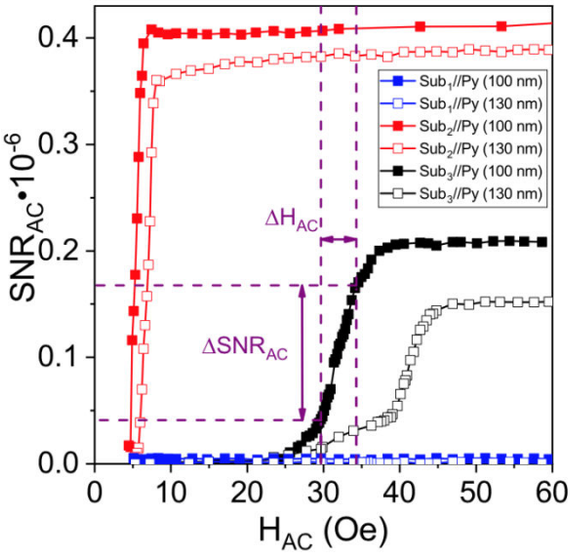


D. Murzin, et al.,
Sensors, 20, 1569, 2020
doi: 10.3390/s20061569

Custom visible-infrared spectroscopy setup

We developed, assembled and automated a custom setup for measuring optical and magneto-optical effects: spectral, angle of incidence and field dependencies in transmission and reflection geometries. The spectral range - 0.35 to 8 um. The temperature - 80 to 300 K. Possibilities include intensity measurements, local magnetometry, circular dichroism measurements.

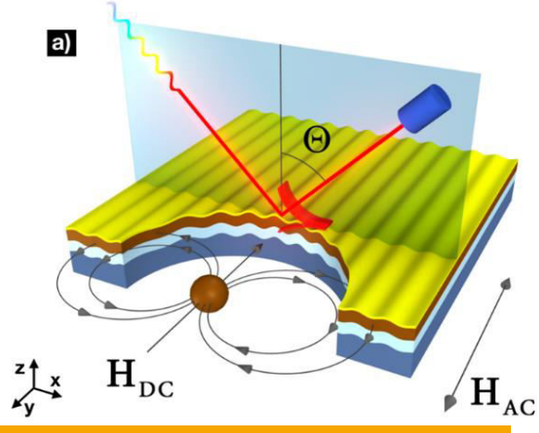




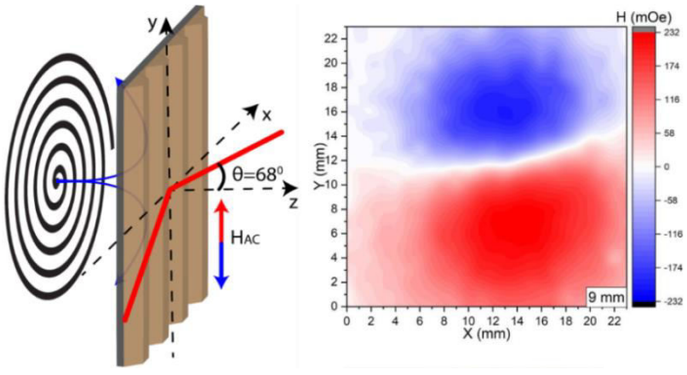
V. Belyaev, et.al.,
JMMM, 482, 292-295, 2019
doi:10.1016/j.jmmm.2019.03.052

Mapping of a DC and AC magnetic field

Magnetoplasmonic crystals can be used as sensitive and local sensors of DC magnetic fields. Demonstrated locality is a square millimeter; sensitivity is 10^{-5}. Currently we are working on protocols for a DC magnetic field mapping and AC field measurements.

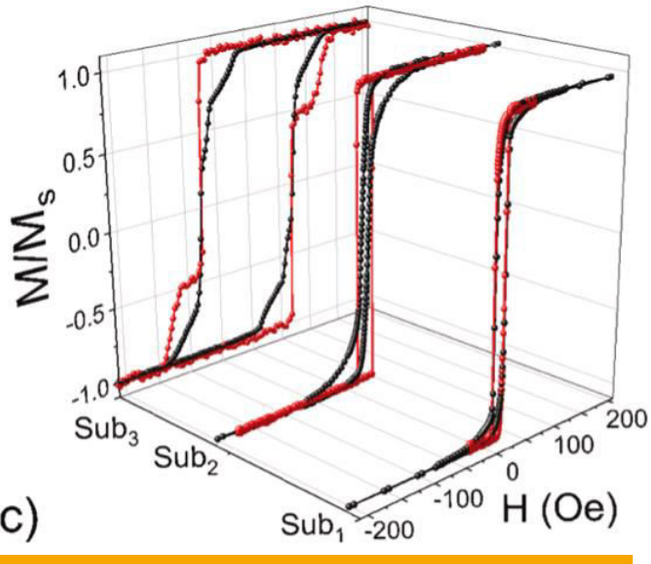


V. Belyaev, et al.,
Sci. Rep., 10(1), 1-6, 2020
doi: 10.1038/s41598-020-63535-1



Local and integral magnetic properties of magnetoplasmonic crystals

The sensitivity of the magnetic field sensor based on magnetoplasmonic crystal mostly depends on magnetic properties and magnetization reversal dynamics, rather than on optical properties. Magnetic, optical and magneto-optical properties can be tuned by the change of composition and thicknesses of functional layers.



V. Belyaev, et al.,
JMMM., 480, 150-154, 2019 doi:
10.1016/j.jmmm.2019.02.032

"Digital Twin" Lab

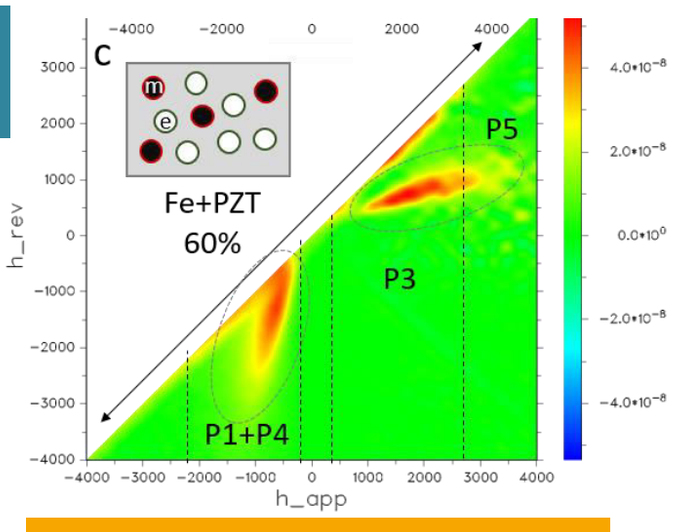
Part of the Sofia Kovalevskaya
Research and Education Mathematical Center

НАУЧНО-ОБРАЗОВАТЕЛЬНЫЙ
МАТЕМАТИЧЕСКИЙ ЦЕНТР
ИМ. С.В.КОВАЛЕВСКОЙ

FORC-analysis, Micromagnetic Simulation, Computer Modeling

FORC-analysis of various magnetic materials

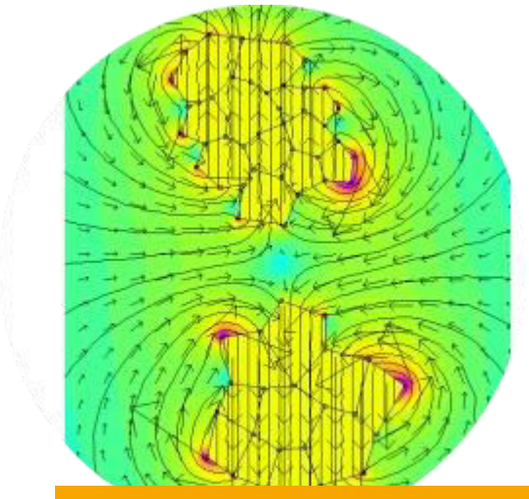
First-order reversal curve (FORC) diagrams provide a sensitive means of probing subtle variations in hysteresis behavior and can help to increase understanding of mechanisms that give rise to hysteresis. The FORC approach has confirmed the presence of magnetic phases of different origins in a polymer-based composite and the change of magnetic properties in such a composite due to the additive ferroelectric particles and applying of an external electric field.



V. Kolesnikova, et al.,
JMMM., 558 (2022) 169506, 2022
doi: 10.1016/j.jmmm.2022.169506

Modeling the domain wall motion in magnetic microwires

A model of head-to-head domain wall in the cylindrical amorphous ferromagnetic microwire with positive magnetostriction is proposed by treating a class of exact particular solutions of Landau-Lifshitz-Gilbert equation in cylindrical coordinates.



A. Omelyanchik, et al.,
Nanomat., 11(5), 1154, 2021
doi: 10.3390/nano11051154

Modeling the interactions between nanoparticles inside a polymer matrix

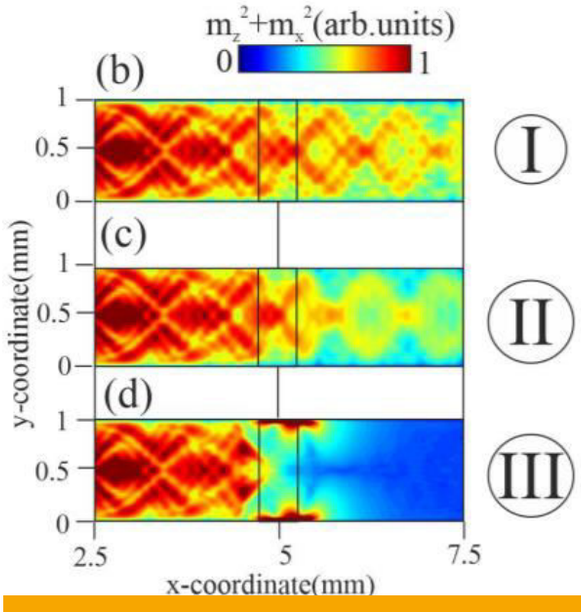
Obtaining of digital twins of polymer-based magnetoelastic composites. Knowing the mechanisms underlying the behavior of the filler particles, gives an opportunity to qualitatively improve synthesis of smart materials with pre-assigned properties.

DFT ab-initio calculations to predict stability and functional properties

Ab-initio calculations are the powerful tool for the search of novel materials and tuning their properties. We use DFT calculations when working with MAX-phases that commonly possess the variety of competing by-phases. That allows us properly optimize synthesis conditions, especially when dealing with a chemical doping. We also use DFT calculations for studying of the adsorption properties of two-dimensional MXenes which can be functionalized with different termination groups. DFT helps us to predict which functionalization will lead to the maximum adsorption capacity towards different pollutants.

Tunable spin wave propagation

We experimentally and theoretically (by the means of micromagnetic simulation) studied a controllable spin-wave propagation in the yttrium iron garnet stripe with the Fe-Rh slab. The qualitative correspondence between the numerical simulation and microwave spectroscopy was observed. It was shown that the geometry variation and design of Fe-Rh slab significantly affect the spin-wave propagation. The proposed structure can be used as a functional unit for planar magnonic networks.



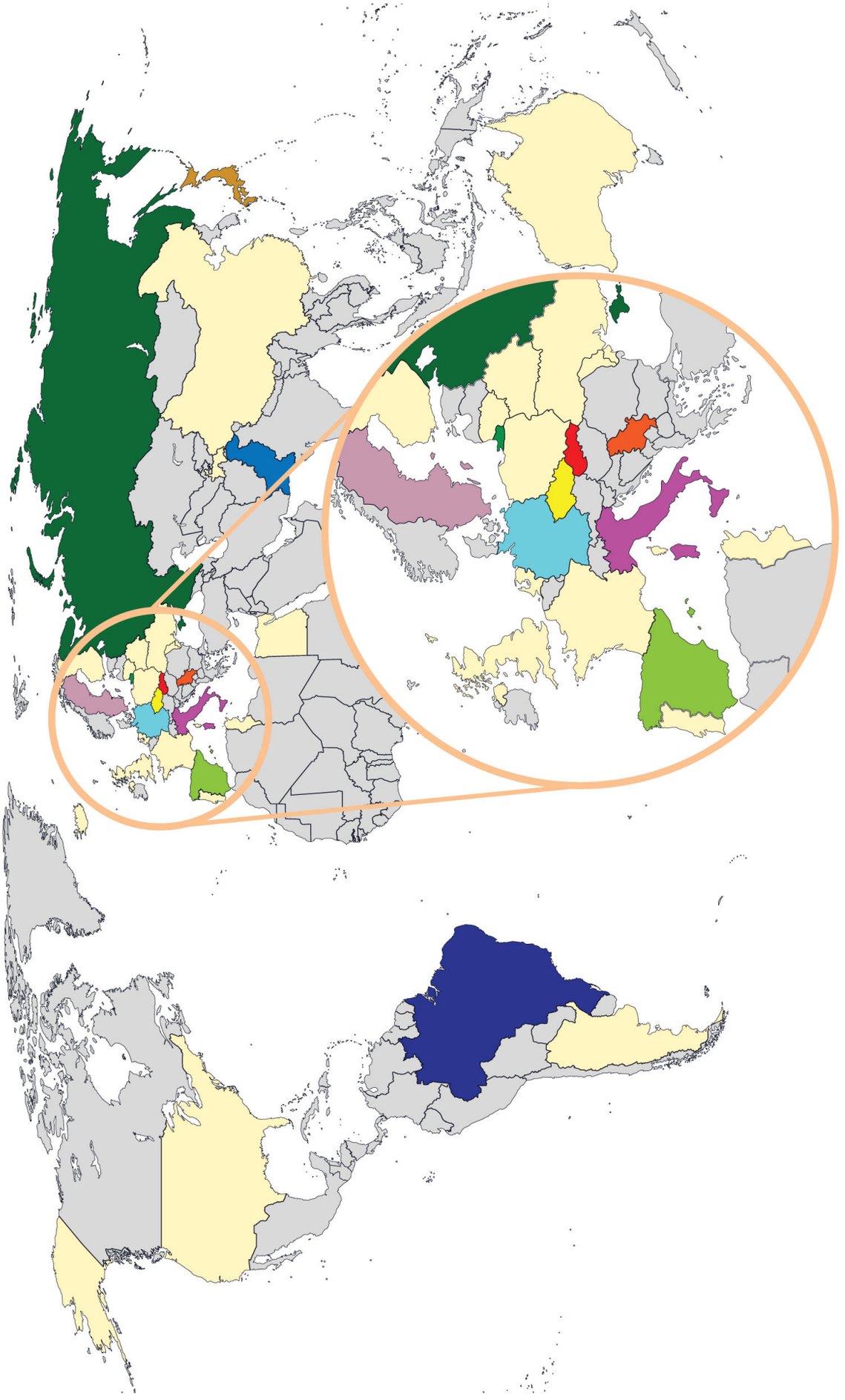
S. Odintsov, et al.,
IEEE Trans. on Magn., 99:1-1, 2021
doi: 10.1109/TMAG.2021.3085402

Our Main Collaborators

- Prof. Andrey Fedyanin, Lomonosov Moscow State University (Moscow, Russia);
- Prof. Nikolay Perov, Lomonosov Moscow State University (Moscow, Russia);
- Prof. Nikolai Chechenin, Lomonosov Moscow State University(Moscow, Russia);
- Prof. Alexander Kamzin, Ioffe Physical-Technical Institute RAS (Saint Petersburg, Russia);
- Prof. Alexey Ognev, Far Eastern Federal University (Vladivostok, Russia);
- Prof. Yuri Raikher, Ural Federal University (Ekaterinburg, Russia);
- Dr. Akhmed Aliev, Amirkhanov Institute of Physics of Dagestan Scientific Center RAS (Makhachkhala, Russia);
- Dr. Alexey Sokolov, Kirensky Institute of Physics RAS (Krasnoyarsk, Russia);
- Dr. Michail Gorshenkov, NUST MISiS (Moscow, Russia);
- Dr. Dmitri Karpenkov, NUST MISiS (Moscow, Russia);
- Dr. Alexey Karpenkov, Dr. Elena Semenova, Tver State University (Tver, Russia);
- Dr. Mikhail Volochaev, Kirensky Institute of Physics, Federal Research Center KSC SB RAS (Krasnoyarsk, Russia);
- Dr. Denis Kozulin, Dr. Roman Vesnin, Vyatka State University (Kirov, Russia);
- Dr. Mikhail Dorokhin, Nizhniy Novgorod State Uniersity (Nizhniy Novgorod, Russia);
- Dr. Alexander Sadovnikov, Saratov State University (Saratov, Russia);
- Dr. Alexander Syuy, Mosow Institute of Physics and Technology (Dolgoprudniy, Russia);
- Prof. Dino Fiorani, ISM-CNR (Rome, Italy);
- Prof. Claudio Sangregorio, ICCOM-CNR (Florence, Italy);
- Prof. Davide Peddis, ISM-CNR and University of Genova, (Genova, Italy);
- Dr. Gaspare Varvaro, ISM-CNR (Rome, Italy);
- Prof. Arkady Zhukov, University of the Basque Country (San Sebastian, Spain);
- Prof. Manuel Vazquez, Institute of Materials Science (Madrid, Spain);
- Prof. Montserrat Rivas, University of Oviedo (Asturias, Spain);
- Dr. Oleg Lunov, Institute of Physics ASCR (Prague, Czech Republic);
- Dr. Anna Pazniak, University Grenoble Alpes (Grenoble, France);
- Prof. Mitsuteru Inoue, Toyohashi University of Technology (Toyohashi, Japan);
- Prof. Rastislav Varga, Institute of Physics of Pavol Jozef Safarik University (Kosice, Slovakia);
- Dr. Vladimír Komanický, P.J. Šafárik University in Košice (Kosice, Slovakia);
- Prof. Rudolf Schäfer, Dr. Ivan Soldatov, Leibniz Institute for Solid State and Materials Research (IFW) Dresden and Technische Universität Dresden (Dresden, Germany);
- Dr. Sonja Javonovic, Vinča Institute of Nuclear Sciences (Belgrade, Serbia) ;
- Dr. Franciscarlos Gomes da Silva, University of Brasília (Brasília, Brazil);
- Dr. Shanawer Niaz, University of Sargodha (Sargodha, Pakistan).

.

And many more



Our scientific events

Smart Composites International School

20 High-level Speakers

68 Young Scientists

25 Lectures

SCIS 2021

53 Practices

Science & Business & Wellbeing

RSF
Russian Science Foundation

In 2021 we started a new series of events – Smart Composites International School (SCIS)

SCIS topics:

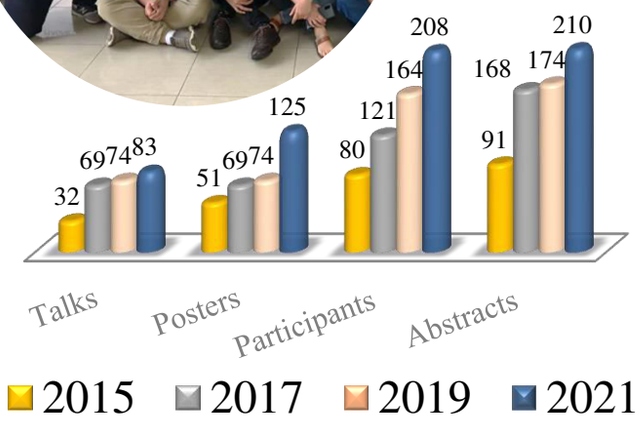
- Magnetic particles
- Piezoelectric particles
- Polymer-based composites
- Smart composites applications

The School is divided into two parts – for beginners and for advancers.

The School is supported by the Russian Science Foundation.

International Baltic Conference on Magnetism is the biannual event focusing on nanomagnetism, smart materials, and nanobiomedicine.

International Baltic Conference on Magnetism



Next IBCM will be held in 2023 and we are pleased to invite you to participate. See you at IBCM 2023!

Smart Materials &
Biomedical Applications
Research and Education Center

Double Degree Master Programme

FUNCTIONAL NANOMATERIALS
AND ADVANCED TECHNOLOGIES

Taplink

Open Vacancies

Smart Composites
International School

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